PROTECTION AGAINST FAULT CURRENT

Short-circuit current

- the short-circuit current that could flow during fault is known as the 'prospective short-circuit current' (PSCC), and any device installed to protect against such a current must be able to break it.
- Figure1 shows PSCC over one half-cycle; t_1 is the time taken to reach the total time taken from start of fault to extinguishing of the arc. ' cut-off' when the current is interrupted, and t_2 the total time taken from start of fault to extinguishing of the arc.
- During the 'pre-arcing' time t_1, electrical energy is passing through the protective device into the conductors. This is known as the 'pre-arcing let-through ' energy and is given by (I_f^2t) where I_f is the short-circuit current at 'cut-off ' The total amount of energy let-through into the conductors is given by (I_f^2t)

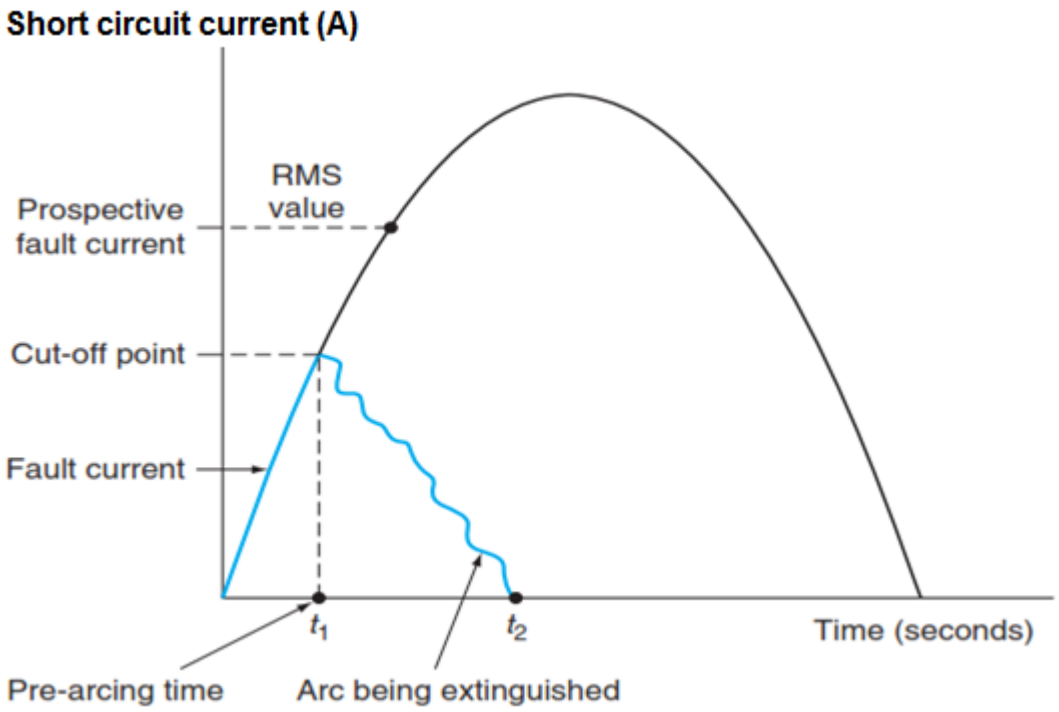


Fig.1

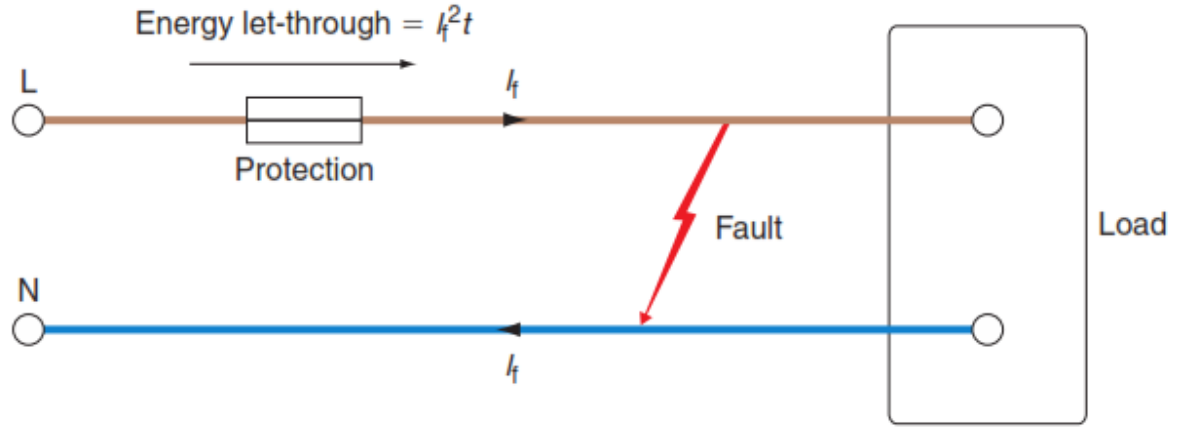


Fig.2

For faults up to 5 s duration, the amount of heat and mechanical energy that a conductor can withstand is given by $K^2 S^2$, where K is a factor dependent on the conductor and insulation materials, and S is the conductor csa.

Evaluation of thermal constraints

During short circuit , the cable is carrying the fault current during the time it takes the protective device to operate and disconnect the circuit. Because this time is very short the cable is heated adiabatically. The fault current depends on the earth fault loop impedance Zs. This impedance is the sum of the impedance of the circuit cable and the impedance of the protective conductor.
In most cases the protective device will have a breaking capacity greater than the prospective short circuit current, and this allows one to assume that the current will be disconnected sufficiently quickly to prevent overheating during a short circuit. The cable size selected from the rating tables for the working current is then adequate.
In other cases a further check must be made by means of the formula

$$s = \frac{\sqrt{I^2 t}}{k}$$

where:

s = minimum csa of the cable
I = fault current
t = disconnection time in seconds
K = Short circuit factor:

K = 115 for copper cables with PVC insulation .

K = 143 for copper cables with XLPE insulation

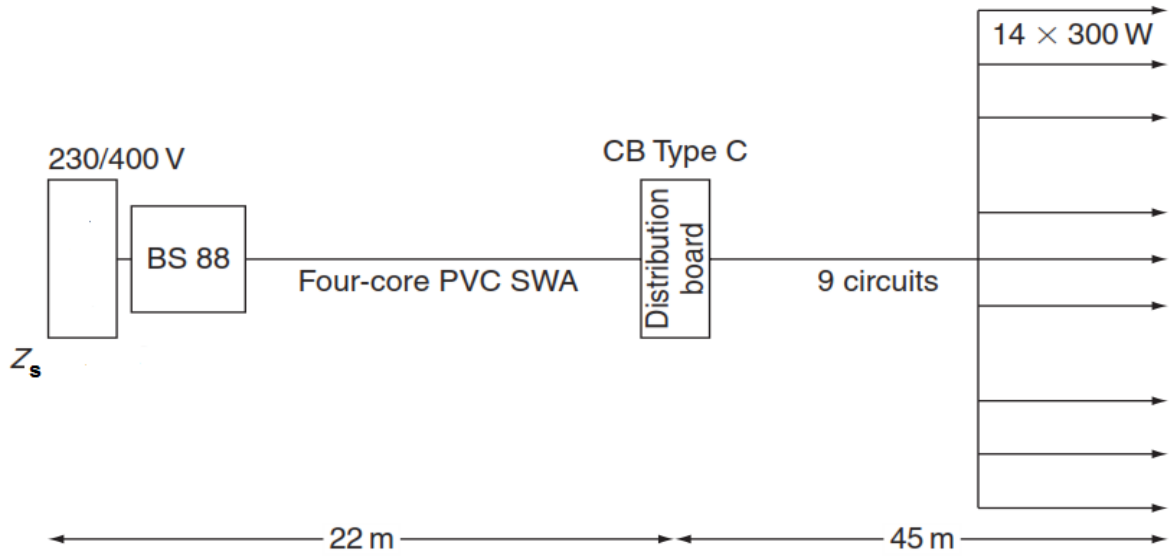
K= 76 for Aluminium cables with PVC insulation

K= 97 for Aluminium cables with PVC insulation

Example 1

Part of the lighting installation in a new warehouse (Hanger) is to comprise a distribution circuit to a three-phase lighting distribution board from which nine single-phase final circuits are to be fed. The distribution circuit, protected by BS 88 fuses, is to be four-core PVC SWA cable and is 22m long(method B1). The distribution board will house Type C CBs, and each final circuit is to supply fourteen 300 W discharge luminaires. The longest run is 45 m, and the wiring system will be singles in trunking(method B1), the first few metres of which will house all nine final circuits. The ambient temperature will not exceed 30°C.

Determine all relevant cable/conductor sizes



Solution

Design current of each final circuit I_b

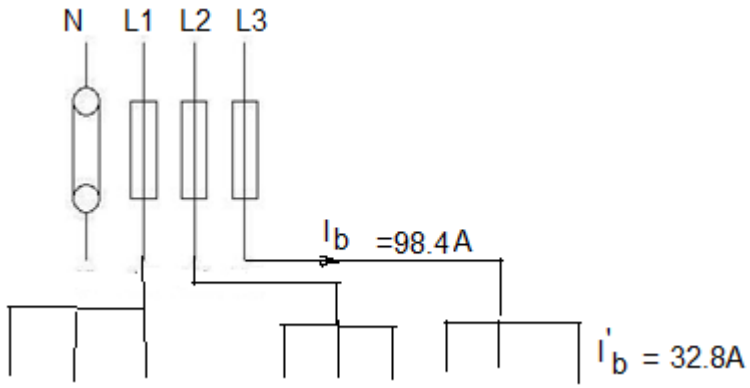
As each row comprises fourteen 300 W/230 V discharge fittings:

$$I_b' = \frac{14 \times 300 \times 1.8}{230} = 32.8\,\text{A}$$

(The 1.8 is the multiplier for discharge lamps)

As the nine circuits will be balanced over three phases, each phase will feed three rows of fittings:

I_b per phase = 3x32.8 = 98.4 A.



Distribution circuit design current I_b

Distribution circuit

I_b per phase = 98.4 A

Nominal rating of protection *In*

$$I_n \geq I_b$$

So, the protection will be 100 A

Tabulated current-carrying capacity I_t

Discharge units do cause short duration overloads at start-up, so it is perhaps best to use I_n rather than I_b:

$$I_t \geq I_n$$
$$\geq 100\,\text{A}$$

Cable selection

From Table (3-5) column 4, I_t = 101 A, giving a cable size of 25 mm ^{2}.

Voltage drop checking:

From IEC Table (3-23) column 4, the mV drop is 1.5.

$$\text{Volt drop} = \frac{1.5 \times 98.4 \times 22}{1000} = 3.23\,\text{V (acceptable)}$$

This is the three-phase drop, the single phase being:

$$\frac{3.23}{\sqrt{3}} = 1.87\,\text{V}$$

Thermal checking:

The impedance of the 25 mm^2 cable from Table (A) is 0.864 Ω/km or 2x0.864 = 1.728 Ω/km (go and return).

$$Z_c = \frac{22x1.728}{1000} = 0.038\Omega$$

$$I = \frac{V}{Z_c} = \frac{230}{0.038} = 6052.6A$$

$$s = \frac{\sqrt{I^2 t}}{k}$$

Let the protection time =0.4 s, then:

$$S = \frac{\sqrt{6052{,}6^2\ x0.4}}{115} = 33mm^2$$

Therefore a cable of 25mm^2 is not adequate, and in this case we use 35mm^2 cable.

Final circuits design current I_b

I_b' = 32.8 A (calculated previously).

Setting of protection I_n

$$I_n \geq I_b = 40\,A$$

From table (3-13) for 9 cables Cg = 0.5

Tabulated current-carrying capacity I_t

$$I_t \geq \frac{I_n}{C_g} \geq \frac{40}{0.5} \geq 80\,A$$

Cable selection

From IEE Regulations Table (3-5) column 4, $I_t \geq 80$ A = 101 A and conductor size will be 25 mm^2.

Voltage drop checking:

From Table (3-23) column 3, the mV drop for a 25 mm^2 conductor is1.51 mV.

$$\text{Volt drop} = \frac{1.51 \times 32.8 \times 45}{1000} = 3\ V$$

Add this to the sub-main single-phase drop, and the total will be:

1.87 + 3 = 4.87 (acceptable)

Thermal checking:

$$Z_c = \frac{45x1.728}{1000} = 0.077\Omega$$

$$I = \frac{V}{Z_c} = \frac{230}{0.077} = 2987A$$

t from Type C CB curve for 32 A is less than 0.1 s. ***K*** = 115 .

$$S = \frac{\sqrt{2987^2\ x0.1}}{115} = 8.2mm^2$$

Hence 25 mm^2 cable is adequate.

Table (A)

X' في درجة حرارة (Ω/كم 70 مئوية)	R' في درجة حرارة (Ω/كم 70 مئوية)	المقطع العرضي وعدد النواقل(mm^2)
0.115	14.47	4x1.5
0.110	8.71	4x2.5
0.107	5.45	4x4
0.100	3.62	4x6
0.094	2.16	4x10
0.090	1.36	4x16
0.086	0.863	4x25
0.083	0.627	4x35
0.083	0.463	4x50
0.082	0.321	4x70
0.082	0.232	4x95
0.080	0.184	4x120
0.080	0.150	4x150
0.080	0.1202	4x185
0.079	0.0922	4x240
0.079	0.0745	4x300